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FRANK LLOYD WRIGHT – CONCRETE IN A MAESTRO'S HANDS

FRANK LLOYD WRIGHT – BETON W RĘKACH MISTRZA

Abstract

Frank Lloyd Wright had many ways of using concrete (and reinforced concrete), creating the spatial forms characteristic of his work. All the structures he designed constitute an aesthetic search for architecture which steers clear of historicism and Art Nouveau and looks towards local tradition for inspiration, whilst taking advantage of new technical opportunities. Gradually, hand in hand with a new way of applying concrete and reinforced concrete in frames, monolithic structures and standard pre-fabricates, Frank Lloyd Wright experimented with new technical solutions. During the Great Depression of the 1930s and the Second World War, he turned to locally available materials in their rawest form, exhibiting the artistic qualities of stones and unformed concrete. In the former case, *concrete block* and *textile block* systems were developed, whilst in the latter a technology which he dubbed *desert rubble stone* was coined and subsequently used for the construction of buildings in the Arizona desert.

Keywords: Frank Lloyd Wright, concrete, reinforced concrete, structure, an idea of industrialization, organic architecture

Streszczenie

Frank Lloyd Wright stosował beton (i żelbet) na wiele sposobów, osiągając charakterystyczne dla swej twórczości efekty formalne. Wszystkie obiekty, które zaprojektował, są poszukiwaniami estetycznymi architektury odchodzącej właśnie od historyzmu i secesji, a poszukującej nowych inspiracji w lokalnej tradycji i nowych możliwościach technicznych. Stopniowo, równolegle z konwencjonalnym sposobem stosowania betonu i żelbetu w szkieletach, konstrukcjach monolitycznych i standardowych prefabrykatach, Frank Lloyd Wright eksperymentował z nowymi rozwiązaniami technologicznymi. W warunkach Wielkiego Kryzysu lat 30. i II wojny światowej zwrócił się ku materiałom lokalnym w najsurowszej ich formie, eksponując walory plastyczne kamieni i nieformowanego betonu. W pierwszym przypadku powstały systemy *concrete block* i *textile block*, a w drugim technologia, którą nazwał *desert rubble stone* i zastosował w budowlach na pustyni Arizony.

Słowa kluczowe: Frank Lloyd Wright, beton, żelbet, konstrukcja, koncepcja uprzemysłowienia, architektura organiczna

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1. Introduction

Frank Lloyd Wright was born in 1867 in Richland Centre, Wisconsin. In 1885, he began studying engineering at the University of Wisconsin but he did not complete his degree. In 1887, he came to Chicago and joined the office of Joseph Lyman Silsbee, then Beers Clay & Dutton, and returned to Silsbee's firm. The same year Wright joined Adler & Sullivan. The first house, which he designed (1897) for his family and gradually extended, was in "Shingle style"[1]. The loan, six children and the opulent social life of the family led him to take up "moonlight jobs". His employers inadvertently found out and he was fired. This marked the beginning of his own practice.

Wright proved to be one of the most influential architects of the early modern era on both sides of the Ocean. His buildings and ideas are still inspiring for new generations of architects. He has completed nearly 500 buildings. Although he is considered to use mostly natural materials in his buildings, he experimented with reinforced structures opening new perspectives for this material.

2. Private and professional life against the background of the economic situation in the USA

The first notable house that influenced American, and later also European architecture, was the Winslow House (1896–1897), with which started *the prairie house* line of residences. During these years, he designed the austere Larkin Building (1903, Buffalo,), the Unity Temple (1904, Oak Park) and the Robbie House (1910, Chicago).

F. L. W. bitterly commented on the change in investors' tastes after the World's Columbian Exposition, held in 1893 in Chicago[2]. Nevertheless, during the time of the Fair, Wright was introduced to the Japanese Pavilion and became fascinated by Japanese culture. In 1905 he visited Japan for the first time, gradually becoming an art collector and connoisseur, which even transpired in the renderings of his designs.

However, taking into account the bullish US economy US and the boom that followed the Exhibition, Wright's career was not so impressive in those years[3].

The following years were even less fortunate. He left his family and in 1909 moved to Europe with the wife of his client, Borthwick (Mamah) Cheney. This led to a scandal resulting in clients abandoning him[4]. The journey they undertook followed a route of the Grand Tour and was used by his English friend, architect, Charles Robert Ashbee to introduce him and his work to European architects. In 1910 The Wasmuth Portfolio: *Ausgefuhrte Bauten und Entwurfe von Frank Lloyd Wright* was published in Germany. This monograph, present-

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[1] An American version of an English late 19th c country house. Characterised by use of shingles – also on the gables and walls and using details from different periods.

[2] S. Giedion, *Czas, przestrzeń, architektura – narodziny nowej tradycji*, Arkady, Warszawa 1968, p. 428.

[3] N. Levine, *The Architecture of Frank Lloyd Wright*, Princeton University Press, Princeton, New Jersey 1996, p. 61.

[4] *Ibidem*, p. 62.

ing Wright's work and reprints of architectural drawings[5], influenced a young generation of architects, future first modernists, and made his reputation in Europe.

Back in America they moved to a new home and studio – Taliesin I, typical of a *prairie house* (and after subsequent fires rebuilt as Taliesin II and III). In 1914 Mamah Cheney, her children, and several members of the staff were murdered by one of the workers, as they tried to flee a fire he had set to the house. At the time Wright was on business in Chicago.

Between 1915 and 1922 Wright was travelling between America and Japan, supervising construction of the Imperial Hotel. In 1923, he married Miriam Noel, but the marriage quickly fell apart. The same year an earthquake and fire destroyed Tokyo, while Wright's Imperial Hotel survived.

In 1919 prohibition struck a blow to many investments and firms, and this soon coincided with the Great Crisis.

During the 1923–1929 period, a new type of a family house was developed by Wright. It was conceived as a cheap solution based on pre-formed blocks of concrete, or reinforced concrete, easily put together – "weaved" together – hence the name "textile block". The external surfaces of the elements showed geometric relief design inspired, again, by pre- Columbian reliefs, widely discussed at that time[6].

Between 1935 and 1936 two buildings were constructed, often considered to be Wright's greatest achievements: the Kaufmann Fallingwater Residence (Pennsylvania 1935) and the Johnson Wax Building (1936, Racine, Wisconsin). These buildings contain many structural and formal innovations that involve experiments with reinforced concrete.

The new Taliesin West house was built in 1937, in Arizona at the time of intense financial struggle. The "desert masonry" technology, created by Wright, stemmed from this situation. After his next marriage, to Olgivanna Lazović-Wright, he established in-resident studies at Taliesin West, the practice of tutoring and working together, which continues there to this day[7].

After the Crisis and at a time of an influx of immigrants from Europe fleeing two dictatorships, Wright was further pursuing the idea of modest, middle-class home on a small plot, with conversion and different finish possibilities. They were partly built in traditional American timber frame style. These "Usonian" (for: useful and: the US) houses were designed and built in compliance with the newest technical standards and were equipped with a *porte-cochère* port for a car[8]. In 1943–1956 Wright designed the spiral structure of the Guggenheim Museum in New York.

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[5] The drawings were prepared by Marion Griffin, one of the first women-architects in the USA, later a co-designer (with her husband) of the general plan for Canberra (Australia); Reid P., Canberra following Griffin, National Archives of Australia, Canberra 2002, p. 354.

[6] J. J. Mark, *Early Explorers of the Maya Civilization: John Lloyd Stephens and Frederick Catherwood* [in:] *Ancient History Encyclopedia*. (2012, July 12), http://www.ancient.eu/article/419/ access 10.06.2017.

[7] N. Levine, *The Architecture of Frank Lloyd Wright*, Princeton University Press, Princeton, New Jersey 1996.

[8] M. Wildman, *An Historical View of Frank Lloyd*, Wright's Usonian Concept, http://www.michaelwildman.com/flw.pdf access: 10.06.2017.

3. Seminal structures and the search for new, economic solutions

More than 500 Frank Lloyd Wright buildings were constructed. Most of them featured some new ideas and solutions, Concrete constructions were also developed. Due to the limited size of this paper, only a few of the most prominent buildings are discussed.

Unity Temple 1904, Chicago

The Unity Temple's internal spaces follow the "compression and release" rule, as the Author described the effect of contrasting sizes of interiors within the building[9]. The spacious interior of the church was lit from the roof skylight. Structurally, due to limited funds, the walls were built as a monolithic structure. While the external walls were under construction, Wright decided to use soap to cover timber forms before concrete was poured, to avoid sealing. Then, after removing the sheeting the walls were scrubbed to uncover the gravel structure of the concrete[10]. A shortage of money prompted the use of relatively minimalist pre-cast pillars that decorate the monumental exterior[11].

Reductions in costs posed large technical problems for recent (2017) comprehensive conservation. The original, deteriorated concrete structure differed from wall to wall, inappropriate renovations added to the problem, but the nearly uniform exterior was finally completed. Woodwork was also restored or replicated and original colours of the interior were uncovered by microscopic forensic analysis.

Robbie House 1910, Chicago

The Robbie House was a "single room type", according to FLW[12]. The best known of the prairie-style homes, from the outside it is distinguished by strong horizontal lines, low-pitched roofs, long strips of windows, a large chimney and brickwork. Brick, plaster and dark wood dominate the colour scheme of the interiors. The open space layout is extended by the terraces and the garden. The exterior walls are double-wythe construction, consisting of a common brick core with a red-orange iron-spotted Roman brick[13] facing. To emphasize the horizontal articulation of walls, horizontal joints were filled with a cream-coloured grout and vertical joints were filled with brick-coloured grout. From a distance, this expensive method of tuckpointing gave the appearance of horizontal layers. It was complemented by limestone and concrete horizontal finishes. Raised plant beds, copings, lintels, sills and other exterior trimworks were made of Bedford limestone and/or concrete.

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[9] J. Koziarz, *Restoration Done Wright: A Look Inside Unity Temple*, https://chicago.curbed.com/2017/6/7/15751444/frank-lloyd-wright-architecture-unity-temple-restoration, access 05.06.2017.

[10] E. Tafel, Apprentice to Genius. Years with Frank Lloyd Wright, McGraw-Hill Book Company, 1979, https://books.google.pl/books?id=oUvBAwAAQBAJ&pg=PT122&lpg=PT122&dq=Wright+Imperial+Hotel++Mueller&source=bl&ots=i0iQPsj6lh&sig=CnOZEF_DQR5dVn1QX_perZBVOmw&hl=pl&sa=X&ved=0ahUKEwiB2NiJyMLVAhXEQBQKHXwkD5QQ6AEIMDAA#v=onepage&q=Wright Imperial Hotel Mueller&f=false, access 10.06.2017.

[11] J. Koziarz, *Restoration Done*…, *op.cit.*

[12] N. Levine, *The Architecture*…, *op.cit.*

[13] It is a name used now for custom-made bricks, longer than standard ones, reminiscent of the ancient Roman bricks used for the structural walls.

Floors and roof structure were supported by steel beams laid on brick piers, which allowed for long windows and open spaces inside[14]. The chimney built using brick and limestone comprised four fireplaces and was accompanied by a timber staircase.

The Imperial Hotel, Tokyo

The Imperial Hotel was functionally divided into two parts: a community centre with open terraces and restaurant for the citizens and a hotel. The symmetrical composition recalls that of the Midway Gardens in Chicago[15].

It was structurally planned to withstand Tokyo's seismic tremors: low buildings were divided into several independent parts. Due to a marshy plot and the low stability of the bed, the construction included floating reinforced concrete foundations with cantilevered elements[16]. A reinforced concrete frame was the basis for this structure. The walls were built as double shelled monolithic construction with the use of light lava (Oya) stone[17]. The construction was executed by builder Paul Mueller, Wright's long-time builder-in-charge[18]. The other elements, such as copper sheeting for the roof, cantilevered balconies and terraces, flexible and accessible media installations laid in ducts and shafts, compensations in pipes, were expected to limit the casualties of earthquakes. The reinforced concrete water pond bowls were perceived as fire extinguishing basins[19].

Hollyhock House

Hollyhock House, built for Aline Barnsdall, was also exposed to seismic activity. Together with the adjoining cultural centre for the performing arts, it was planned near to the top of the hill overlooking Hollywood. Pre-Columbian architecture was the reference for its form and hollyhock flowering shoots were chosen for a decorative motif. Discussions over the size, shape and programme lasted several years (1915–1925), even when the first buildings were under construction. The whole enterprise was never finished.

Due to a shortage of money, there were two options for the walls: solid brickwork or timber frame covered with concrete panels and plastered to achieve a "solid" image. Finally, Wright used hollow clay bricks and plaster instead. These materials made the structure susceptible to water and seismic damage[20]. The beams used in most parts of the structure were of reinforced concrete and entrance swinging doors were made of raw concrete panels, em-

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[14] http://www.monografias.com/trabajos101/the-robie-house-desmitificacion-ilusion/the-robie-house-desmitificacion-ilusion.shtml, access 05.05.2017.

[15] K. Frampton, *Modern Architecture: a critical history*, Thames and Hudson 1994, p. 62–63.

[16] F. L. Wright, *Frank Lloyd Wright: An Autobiography*, Pomegranate Communications, Inc., Warwick (UK) 2005, access 10.06.2017, https://books.google.pl/books?id=S8zlZcJjNEMC&pg=PA191&redir_esc=y#v=onepage&q&f=false

[17] N. Levine, *The Architecture of Frank Lloyd Wright*, Princeton University Press, Princeton, New Jersey 1996, p. 121.

[18] E. Tafel, *Apprentice to Genius…op.cit.*

[19] A full report of the damage after the 1923 Great Kanto Earthquake was summarized by Robert K. Reitherman, Frank Lloyd Wright's Imperial Hotel: a seismic re-evaluation, http://www.iitk.ac.in/nicee/wcee/article/7_vol4_145.pdf

[20] blogs.getty.edu/iris/12-things-you-didnt-know-about-frank-lloyd-wrights-hollyhock-house access 05.05.2017.

bossed and containing glass panes[21]. This unexpected detail made a statement of the versatility of concrete in the hands of F.L.W.

There are two contradicting versions concerning finishing material of the prominent fireplace and the abstract relief over it. The document: Supplemental Historic Structure Report refers to stone cladding of the chimney and the bas-relief[22]. According to the article "12-Things You Didn't Know About Frank Lloyd Wright's Hollyhock House"[23] and the book "Frank Lloyd Wright Fireplaces" by Carla Lind[24], the fireplace and the bas-relief are made of cast concrete.

Extensive outside furnishings: walls, steps, terraces, bowls of the two ponds and decorative details were also made of concrete cast *in situ* or pre-cast.

Concrete Block and Textile Block, 1923–1929

During the 1923–1929 period, a new type of a house, built with prefab elements was introduced by Wright[25]. At that time, he considered that production of typical, concrete elements, larger than bricks (40 x 40 cm approx.) and joined by steel reinforcing bars "woven" vertically and horizontally in between them, would be cheaper and easier. The technology was named *textile block*. Wright designed houses with a utopian vision that homeowners could build these houses themselves, using affordable materials and a site-specific place. This idea was risky in the Los Angeles seismic area. Furthermore, Wright's clientele in those days was in the above-average income group and the Architect himself belonged already to the most respected[26]. Wright built four houses using this technology, which proved to be more laborious and complicated than ordinary constructions as it demanded many more types of blocks than was expected, and skilled labour. This idea was developed in Usonian houses, which became "typical" in a different way: the flexibility of their function became the main feature, enabled by a risen central part of the house which allowed light into the hub of the living space.

The external surfaces of the elements showed geometrical relief designs inspired by pre-Columbian reliefs, widely discussed at that time[27]. Detailed descriptions of how the system was produced and mounted survived[28]. The walls were either one or two layers thick, and

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[21] A. G. Kudler, *A Full Tour Through Frank Lloyd Wright's First LA House, Restored to Its 1920s' Beauty*, https://la.curbed.com/2015/2/13/9992116/a-full-tour-through-frank-lloyd-wrights-first-la-house-restored-to, access 05.05.2017.

[22] Supplemental Historic Structure Report, Hollyhock House, City of Los Angeles, Los Angeles County, California, October 2009, access: 10.05.2017. http://ens.lacity.org/restore/ph_house/restoreph_house298959039_03242009.pdf /

[23] blogs.getty.edu/iris/12-things-you-didnt-know-about-frank-lloyd-wrights-hollyhock-house access 05.05.2017.

[24] C. Lind, *Frank Lloyd Wright Fireplaces*, Archetype Press 1995, p. 36, https://books.google.pl/books/about/Frank_Lloyd_Wright_s_Fireplaces.html?id=bLhzVFoe6JQC&redir_esc=y, access 10.06.2017

[25] P. Bigaj, *Prefabrykowane technologie betonowych rezydencji Franka Lloyda Wrighta – textile block system*, Technical Transactions, Architecture, 7-A/2012, p. 4–23.

[26] A. Walker, *Frank Lloyd Wright's forgotten Hollywood sandcastle*, access: 10.06.2017. https://www.curbed.com/2017/6/8/15742110/samuel-freeman-house-frank-lloyd-wright-los-angeles

[27] J. J. Mark, Early Explorers of the…, *op.cit.*

[28] http://wrightchat.savewright.org/viewtopic.php?t=9516&sid=009457b909496c20c460bf761af28970 access 05.05.2017.

built as cavity walls. Concrete blocks were pre-cast in forms made of timber or metal, which gave them reliefs on the facing side and made it possible to perforate the blocks. Perforations provided latticework elements for internal or external walls and as some perforations were glazed, they allowed light to seep into the interiors[29].

The final appearance of these buildings with open layouts and sheltered yards was unusual, with their intricate wall texture and light effects. These were Ennis House, Freeman House in Hollywood and Storer House in Los Angeles. Each of them had a different, geometric, Mayan originated relief.

As their quality was often poor and joints susceptible to water permeance, the buildings posed problems from the very beginning. Even in Wright's times they underwent major repairs[30].

Recent conservation work, which sometimes went beyond the recognized conservation methods, enabled two of the houses (Freeman and Ennis) to achieve contemporary standard within the spectrum of Wright's aesthetic ideas[31].

Kaufmann Fallingwater Residence (1935)

The house was designed as a weekend home for the family of Liliane and Edgar J. Kaufmann, owners. It was built partly over a waterfall on Bear Run in the Stewart Township in Pennsylvania.

Wright often pursued an idea of the building looking as if defying gravity. Therefore, he often used cantilevers, which were sometimes extended farther from supports than engineering practice advised. In the case of Fallingwater, the location and vision demanded the use of cantilevered floors supporting the structure containing the main part of the house. As some of his cantilevered structures had failed before, Kaufmann commissioned engineering studies to determine whether the distortions observed in the house just after it was built could pose a serious threat to safety[32].

The structural design for Fallingwater was undertaken by Wright in association with engineers Mendel Glickman and William Wesley Peters[33]. An old quarry was opened to supply local stone for the construction and finishes. The works started in 1936. Byron K. Mosher, an apprentice of FLW was in charge of the building process[34].

Strong horizontal, warm yellow-brown concrete elements and horizontally articulated stone walls are characteristic of Fallingwater. They were a result of slate stone walls supporting linear floors, balustrades, roofs and eaves made of reinforced concrete.

The construction was a source of constant conflicts between FLW, Kaufmann and engineers. Wright agreed to strengthen the main floor that overhangs two metres with more steel,

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[29] P. Bigaj, *Prefabrykowane technologie betonowych*…, *op.cit.*

[30] *Ibidem*.

[31] A. Walker, *Frank Lloyd Wright's forgotten*…, *op.cit.*

[32] http://www.williamcronon.net/writing/cronon_inconstant_unity_passion_of_frank_lloyd_wright_1994.pdf, access 10.06.2017.

[33] William Wesley Peters had been also responsible for the "mushroom" columns in Wright's design of Johnson Wax Company Headquarters.

[34] D. Hoffmann, *Frank Lloyd Wright's Fallingwater: The House and Its History*, Dover Publications, Inc., New York, 1993, p. 34.

but it proved too small a change and needed repairs later[35]. Agreed changes to the structure not co-ordinated with FLW did not stop a noticeable sagging of the construction which was the reason for a series of repairs.

In 1995, the Western Pennsylvania Conservancy commissioned a study of Fallingwater's structural integrity. These showed that the contractor had added reinforcement over Wright's plan but the floors were still insufficiently reinforced. In 1997, temporary girders were installed beneath the cantilevers[36].

The last restoration action was undertaken in 2001. In 2002, the structure was repaired using post-tensioning. All the floors were removed, blocks were joined to the concrete cantilever beams and floor joists, high-strength steel cables were fed through the blocks and exterior concrete walls and tightened. The floors and walls were then restored, leaving Fallingwater's interior and exterior appearance unchanged[37].

Johnson Wax Building, 1936, Racine

The Johnson Wax Headquarters were built in an industrial part of Racine. The complex is considered to be Wright's interpretation of Art Deco. Curved walls were built with bricks that varied in size and curvature: there were 200 types of such "Cherokee red", local bricks. As in the former buildings, the mortar between them was tuckpointed to accentuate horizontal lines. The red of the bricks was mirrored by the concrete finish of the floor slabs.

The columns were the most prominent elements of the interiors. In the Great Workroom, Wright used them as slender, tree-like forms, two storeys tall and in the covered car park, by the entrance, they were short and stocky. Again "compression and release" was exploited by the architect to contrast the entrance space and the interior to ensure an impact upon arrival[38].

The Great Workroom columns, with mushroom-like circular capitals, that nearly touched one another, formed the ceiling. The spaces between the circles were closed with a surface of Pyrex glass tubes letting the light in. Use of glass tubes was extended to the translucent friezes on the top of walls. From the outside, glass strips followed and underlined exposed tie-beams of the floors and roofs.

Precast "mushroom" columns were supported by joints 23 cm in diameter and their capitals were 550 cm in diameter at the top. This created controversies for Wright, as the construction did not comply with building regulations. A test demanded by the authorities, proving that a column could withstand a twelve-ton load, ended when the 60 tons of load destroyed it.

The Research Tower for the complex was built ten years later. It exploits the possibilities of reinforced concrete construction of high rise buildings. The core of the building houses a lift, staircase, toilets and technical shafts, Floor slabs, thinner towards the elevation, support it on every second floor. Between them smaller, circular floors are confined by internal

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[35] *Ibidem*, p. 32.

[36] R. Silman, J. Matteo, *Repair and Retrofit. Is Fallingwater Falling Down?*, https://web.archive.org/web/20070927013737/http://www.structuremag.org/archives/2006/Falling%20Water/FallingWater.pdf access: 10.06.2017.

[37] R. Silman, *The Plan to Save Fallingwater*, Scientific American, 2000, 283(3), p. 88–95, access 10.06.2017, https://documentslide.com/documents/the-plan-to-save-fallingwater.html

[38] N. Levine, *The Architecture of*…, *op.cit.*

brick balustrades creating mezzanines. The whole construction is encased in Pyrex glass wall made of tubes[39].

Taliesin West in Arizona, 1937

This house became Frank Lloyd Wright's winter desert home from 1937, until his death in 1959. The construction was started by Wright and a group of his apprentices at the time of intense financial struggle. A new desert environment and the lack of possibilities to build in a traditional way brought new solutions that stemmed from the situation. Native American petroglyphs were found on the rocks and they became a symbol of the place and an inspiration. The open desert with boulders scattered around influenced a new kind of construction: use of stones in their natural shape and concrete in its most basic form. The system demanded unskilled workmanship and was called "desert masonry".

Stones of different sizes were stacked in layers in timber boarding, with flat surfaces outward, to create the wall facing. The spaces between them were filled with concrete. This resulted in rough surfaces of intertwined stone and concrete matter. After dismounting the timber forms, the outer surface with the concrete not completely set had to be cleaned. Patches of concrete had to be chiselled off. Walls of different kinds, pillars and outside landscaping were made using the "desert masonry" technology[40].

For technical reasons, the ceilings of this single floor house were made of timber beams and originally covered with translucent canvas which constituted the roof. Now, they are replaced with plastic and blinds, because of the Arizona sun.

Wright expanded Taliesin West by many additions: rooms, terraces and the theatre.

Recent conservation work carried out in Taliesin (2017) focus on the reconstruction of pillars that were damaged[41].

Guggenheim Museum, 1943–1956, New York

The Guggenheim Museum was an embodiment of Wright's attempts to incorporate organic form into architecture and at the same time, plan for the building manifestoed new approach to a museum design. The exposition developed along a continuous ramp from the starting point at the top, to the ground floor of the building. The view of the internal open space was covered with a ceiling skylight and lower levels of exposition accompanied the visitor.

The only contractor who agreed to undertake this task, was a company whose experience covered car park and road constructions.

Three types of concrete are used throughout the building: light-weight concrete is used in the ramp and floors, stone concrete was used for the internal walls to assure a smooth finish. The outer shell of the Museum was constructed of "gun-concrete" – gunite[42], a monolithic

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[39] http://www.archdaily.com/544911/ad-classics-sc-johnson-wax-research-tower-frank-lloyd-wright, access 10.06.2017.

[40] http://taliesin.edu/history/, access 10.06.2017.

[41] *Rebuilding Desert Masonry*, Frank Lloyd Wright Foundation, Mar 16, 2017, access: 10.06.2017. http://franklloydwright.org/rebuilding-desert-masonry/

[42] This construction, new in those days, demands experienced specialists, and typically was used for cooling towers in industrial plants. Wright chose it as a substitute solution, when the costs of stone finish, which he planned, turned out to be too high.

technology of concrete, sprayed from the inside onto a steel reinforcement mesh[43]. The form for this 12.5 cm thick wall was made with steel frame and bent plywood panels. Circular and sloping walls were rigidly connected to the spiral ramp. The outside face was smoothed and plastered while it was still fresh. At first, the wall had to be painted red. Finally, light, yellow-brown was applied, which after many re-paintings turned into greyish-white.

The main ramp cantilevers 4.42 m to the inner court from a 33 cm deep rigid beam of changing width. Since the greater widths occur at the higher levels, the overall width of the ramp increases as it spirals upward.

The inside spiral ramp carries 90 cm high plaster parapet[44]. The structure was built with 198.2179 m^3 of concrete and 700 tons of structural steel.

Wright's part of the Museum underwent massive conservation work in 2005–2008. Detailed research on the technical situation of the structure and original finishes was undertaken. The aim of the work was to keep as much as possible of the original fabric of the building.

4. Summary

The use of new materials was unavoidable to achieve the objectives set by Wright: construction of a structure with a new spatial concept and artistic expression. Concrete and reinforced concrete had many uses, which the architect made full use of. The most recent maintenance work carried out on the structures in question clearly showed that vision was the most powerful element in Wright's works. To fulfil it, he was willing to take risks, enter conflicts and also to follow new technical achievements.

The above paper uses three types of publications: articles dating back to the time when the buildings were erected or shortly after, a number of Wight's recognised biographical publications as well as materials describing upgrade works which took place in recent years. The analysis covers nine key structures for Frank Lloyd Wright's creative work.

Their seminal concepts and solutions, technical and technological experiments opened up new paths, which were observed and used all around the world.

References

[1] Bigaj P., *Prefabrykowane technologie betonowych rezydencji Franka Lloyda Wrighta – textile block system*, Technical Transactions, Architecture, 7-A/2012, p. 4–23.

[2] Cohen G. N., *Frank Lloyd Wright's Guggenheim Museum*, Concrete Construction, March 01, 1958. access 05.06.2017. http://www.concreteconstruction.net/how-to/construction/frank-lloyd-wrights-guggenheim-museum_o

[3] Frampton K., Modern Architecture: a critical history, Thames and Hudson 1994.

[43] G. N. Cohen, *Frank Lloyd Wright's Guggenheim Museum*, Concrete Construction, March 01, 1958, access 05.06.2017, http://www.concreteconstruction.net/how-to/construction/frank-lloyd--wrights-guggenheim-museum_o

[44] *Ibidem*.

[4] Giedion S., *Czas, przestrzeń, architektura – narodziny nowej tradycji*, Arkady, Warszawa 1968.
[5] Goessel P., Leuthaeuser G., *Architektura XX wieku*, Taschen 2006.
[6] Hoffmann D**.,** *Frank Lloyd Wright's Fallingwater: The House and Its History*, Dover Publications, Inc., New York 1993.
[7] Koziarz J. Restoration Done Wright: A Look Inside Unity Temple, https://chicago.curbed.com/2017/6/7/15751444/frank-lloyd-wright-architecture-unity-temple-restoration, access 05.06.2017.
[8] Kudler A. G., A Full Tour Through Frank Lloyd Wright's First LA House, Restored to Its 1920s' Beauty, https://la.curbed.com/2015/2/13/9992116/a-full-tour-through-frank-lloyd-wrights-first-la-house-restored-to, access 05.05.2017.
[9] Levine N., *The Architecture of Frank Lloyd Wright*, Princeton University Press, Princeton, New Jersey 1996.
[10] Lind C., *Frank Lloyd Wright Fireplaces*, Archetype Press 1995, p. 36, https://books.google.pl/books/about/Frank_Lloyd_Wright_s_Fireplaces.html?id=bLhzVFoe6JQC&redir_esc=y, access 10.06.2017
[11] Mark, J. J, *Early Explorers of the Maya Civilization: John Lloyd Stephens and Frederick Catherwood*, [in:] *Ancient History Encyclopedia*. (2012, July 12), http://www.ancient.eu/article/419/, access 10.06.2017.
[12] Rebuilding Desert Masonry, Frank Lloyd Wright Foundation, Mar 16, 2017, access: 10.06.2017, http://franklloydwright.org/rebuilding-desert-masonry/
[13] Reitherman R. K., F*rank Lloyd Wright's Imperial Hotel: a seismic re-evaluation*, access: 10.06.2017, http://www.iitk.ac.in/nicee/wcee/article/7_vol4_145.pdf
[14] Reid P., *Canberra following Griffin*, National Archives of Australia, Canberra 2002.
[15] Silman R., Matteo J., R*epair and Retrofit. Is Fallingwater Falling Down?*, https://web.archive.org/web/20070927013737/http://www.structuremag.org/archives/2006/Falling%20Water/FallingWater.pdf, access: 10.06.2017.
[16] Silman R, *The Plan to Save Fallingwater*, Scientific American, 2000, 283(3), access 10.06.2017, https://documentslide.com/documents/the-plan-to-save-fallingwater.html
[17] Supplemental Historic Structure Report, Hollyhock House, City of Los Angeles, Los Angeles County, California, October 2009, access: 10.05.2017. http://ens.lacity.org/restore/ph_house/restoreph_house298959039_03242009.pdf /
[18] Tafel E., *Apprentice to Genius. Years with Frank Lloyd Wright*, McGraw-Hill Book Company, 1979, https://books.google.pl/books?id=oUvBAwAAQBAJ&pg=PT122&lpg=PT122&dq=Wright+Imperial+Hotel++Mueller&source=bl&ots=i0iQPsj6lh&sig=CnOZEF_DQR5dVn1QX_perZBVOmw&hl=pl&sa=X&ved=0ahUKEwiB2NiJyMLVAhXEQBQKHXwkD5QQ6AEIMDAA#v=onepage&q=Wright Imperial Hotel Mueller&f=false, access 10.06.2017.
[19] Walker A., *Frank Lloyd Wright's forgotten Hollywood sandcastle*, access: 10.06.2017. https://www.curbed.com/2017/6/8/15742110/samuel-freeman-house-frank-lloyd-wright-los-angeles
[20] Wildman M., *An Historical View of Frank Lloyd, Wright's Usonian Concept*, http://www.michaelwildman.com/flw.pdf access: 10.06.2017.
[21] Wright F. L., Frank Lloyd Wright: An Autobiography, Pomegranate Communications, Inc., Warwick (UK) 2005, access 10.06.2017, https://books.google.pl/books?id=S8zlZcJjNEMC&pg=PA191&redir_esc=y#v=onepage&q&f=false

Web pages:

http://www.monografias.com/trabajos101/the-robie-house-desmitificacion-ilusion/the-robie-house-desmitificacion-ilusion.shtml, access 05.05.2017.
blogs.getty.edu/iris/12-things-you-didnt-know-about-frank-lloyd-wrights-hollyhock-house/, access 05.05.2017.
http://ens.lacity.org/restore/ph_house/restoreph_house298959039_03242009.pdf, access 10.06.2017.
blogs.getty.edu/iris/12-things-you-didnt-know-about-frank-lloyd-wrights-hollyhock-house access 05.05.2017.
http://wrightchat.savewright.org/viewtopic.php?t=9516&sid=009457b909496c20c460bf761af28970 access 05.05.2017.
http://www.williamcronon.net/writing/cronon_inconstant_unity_passion_of_frank_lloyd_wright_1994.pdf, access 10.06.2017.
http://www.archdaily.com/544911/ad-classics-sc-johnson-wax-research-tower-frank-lloyd-wright, access 10.06.2017.
http://taliesin.edu/history/, access 10.06.2017.